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(54) **SELF INITIATED PRONE PROGRESSIVE CRAWLER**

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USPC 280/250.1; 601/5; 623/24
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,992,023 A 11/1976 Moorer
4,569,532 A 2/1986 Mirkarimi

(Continued)

FOREIGN PATENT DOCUMENTS

MX 2008015471 A 9/2010

OTHER PUBLICATIONS

Vardhman Sheth, Accelerometer Controlled Robot, Mar. 16, 2012, sites.google.com.*

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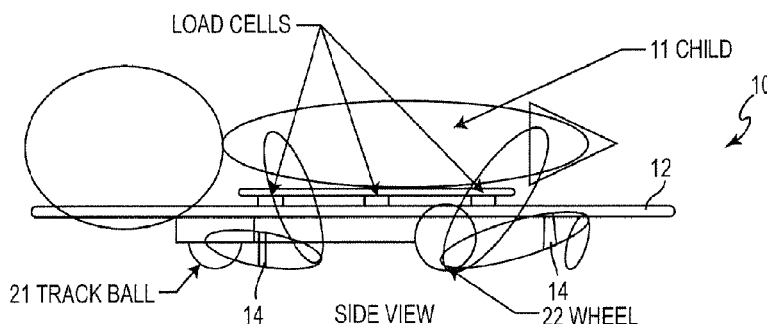
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(57) **ABSTRACT**

A self initiated prone progressive crawler facilitates crawling in infants by sensing the infant's intent and assisting movement. The device is designed as a mobility aid to assist an infant in prone locomotion. The infant can be placed in a prone position on a platform and secured with hook and loop straps. The arms and legs are unconstrained and are able to reach the floor comfortably. The self initiated prone progressive crawler is a motorized wheeled platform which has three points of contact with the ground. One point is an industrial trackball, mounted upside down to provide positional and positional derivative data to a controller. It is located roughly under the chest of the infant and is highly sensitive to movement. The other points of contact are two DC torque motors which are controlled by the controller. In addition to the positional and positional derivative data provided to the controller, the controller also receives data from four equally spaced load cells on a force plate and tri-axial accelerometer gyros attached to the upper and lower extremities of the child. The load cells provide force information between the infant and the device to allow weight shifts to be assessed and used as a control parameter. The accelerometer gyros generate data that provides patterns that can be correlated with crawling movements.

21 Claims, 13 Drawing Sheets



(51)	Int. Cl.		5,299,454 A *	4/1994	Fuglewicz et al.	73/172
		<i>A47D 13/04</i>	(2006.01)	5,324,064 A	6/1994	Sumser
		<i>A47D 13/08</i>	(2006.01)	5,368,532 A *	11/1994	Farnet 482/5
		<i>G05D 1/00</i>	(2006.01)	5,639,105 A *	6/1997	Summo 280/250.1
(52)	U.S. Cl.		6,019,705 A	2/2000	Thom	
		CPC	6,244,991 B1	6/2001	Bingham	
		<i>A61G 2200/14</i> (2013.01); <i>A61G 2200/325</i>	6,983,813 B1 *	1/2006	Wright 180/11	
		(2013.01); <i>A61G 2203/32</i> (2013.01); <i>A61G</i>	7,157,875 B2 *	1/2007	Kamen et al. 318/434	
		<i>2203/42</i> (2013.01)	7,182,351 B2	2/2007	Williams	
		USPC	7,183,910 B2 *	2/2007	Alvarez et al. 340/539.13	
		701/22 ; 601/5; 280/250.1; 280/149.2;	7,544,172 B2 *	6/2009	Santos-Munne et al. 601/5	
		623/24	8,419,804 B2 *	4/2013	Herr et al. 623/24	
			2005/0278857 A1	12/2005	Fairchild	
			2011/0009245 A1	1/2011	Flowers	
(56)	References Cited					
		U.S. PATENT DOCUMENTS				
		4,629,950 A *	12/1986	Ching	318/285	* cited by examiner

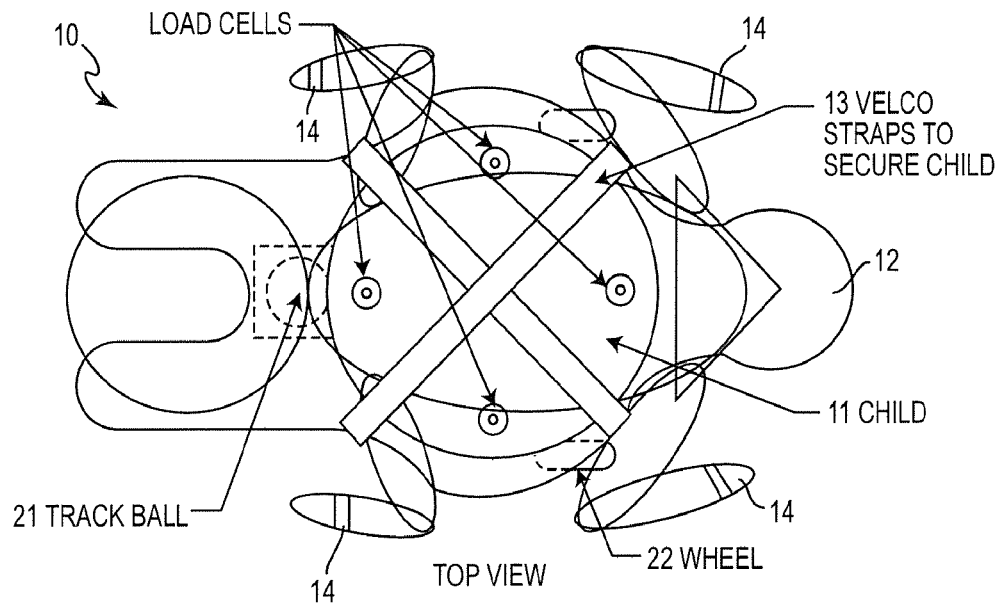


Fig. 1a

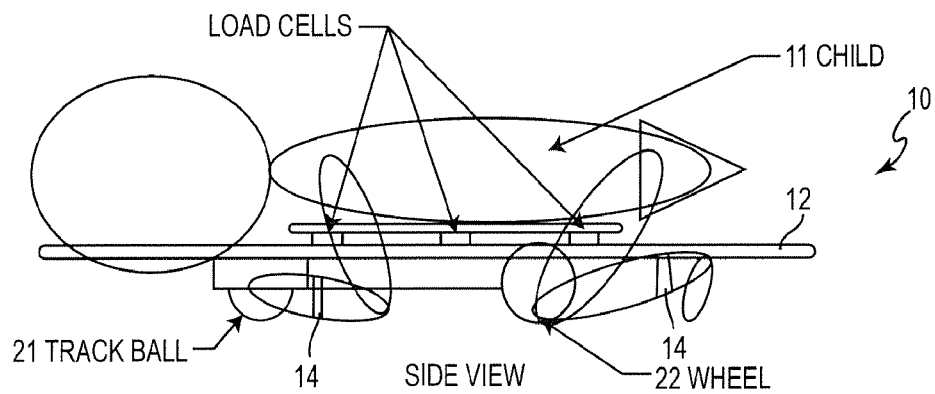


Fig. 1b

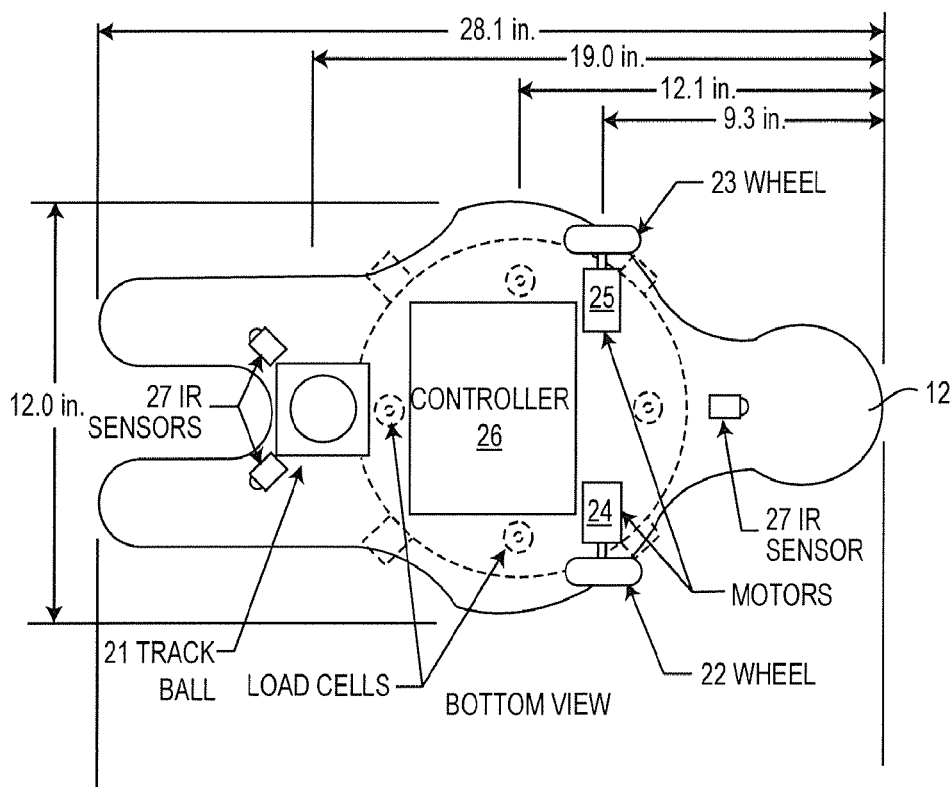


Fig. 2a

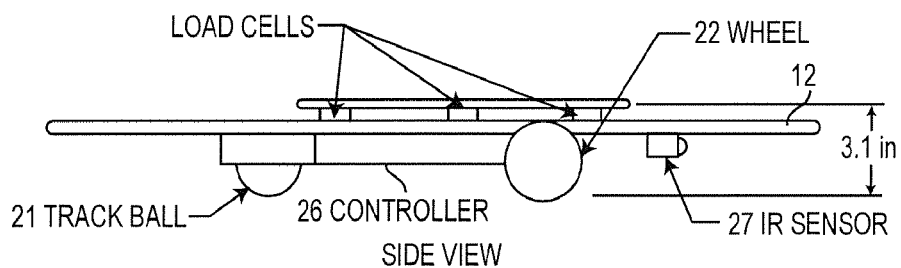


Fig. 2b

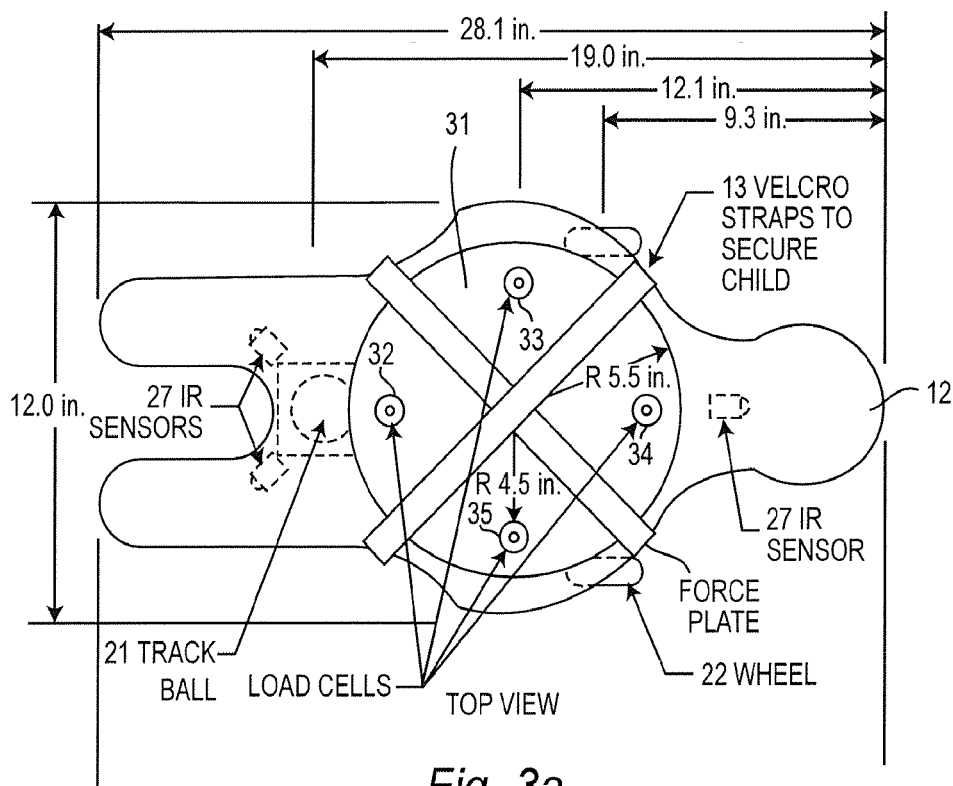


Fig. 3a

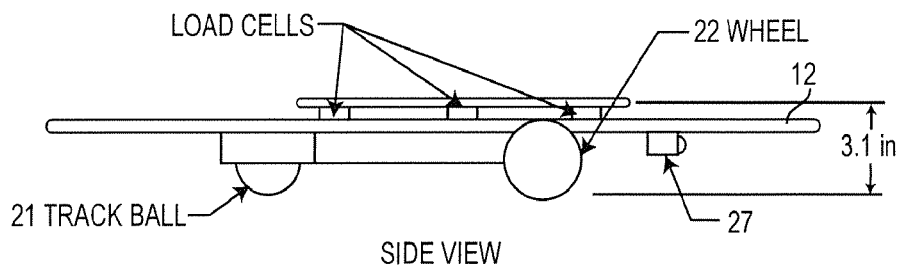


Fig. 3b

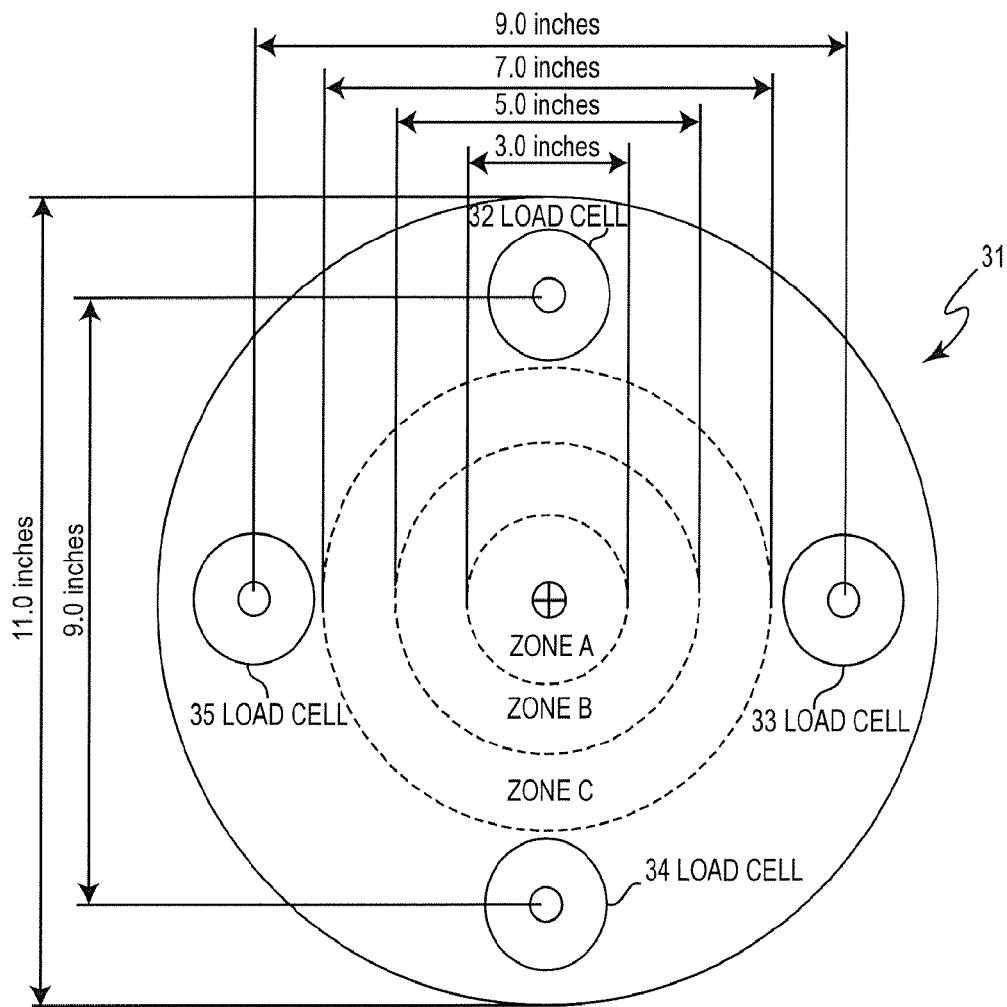
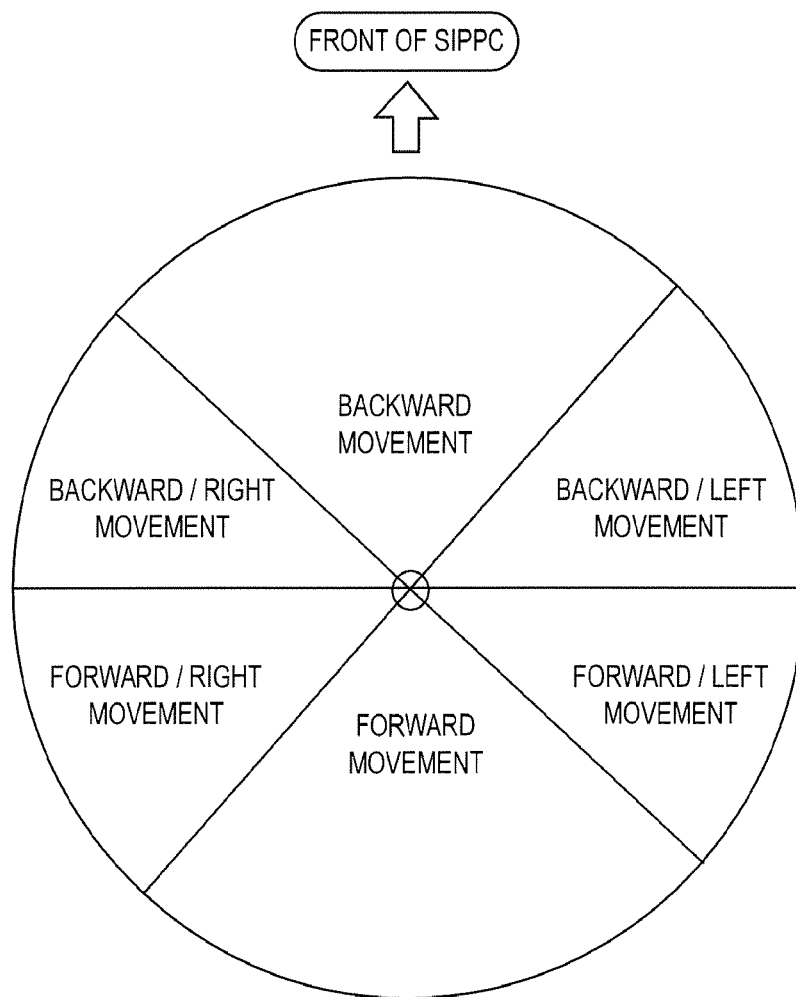


Fig. 4

*Fig. 5*

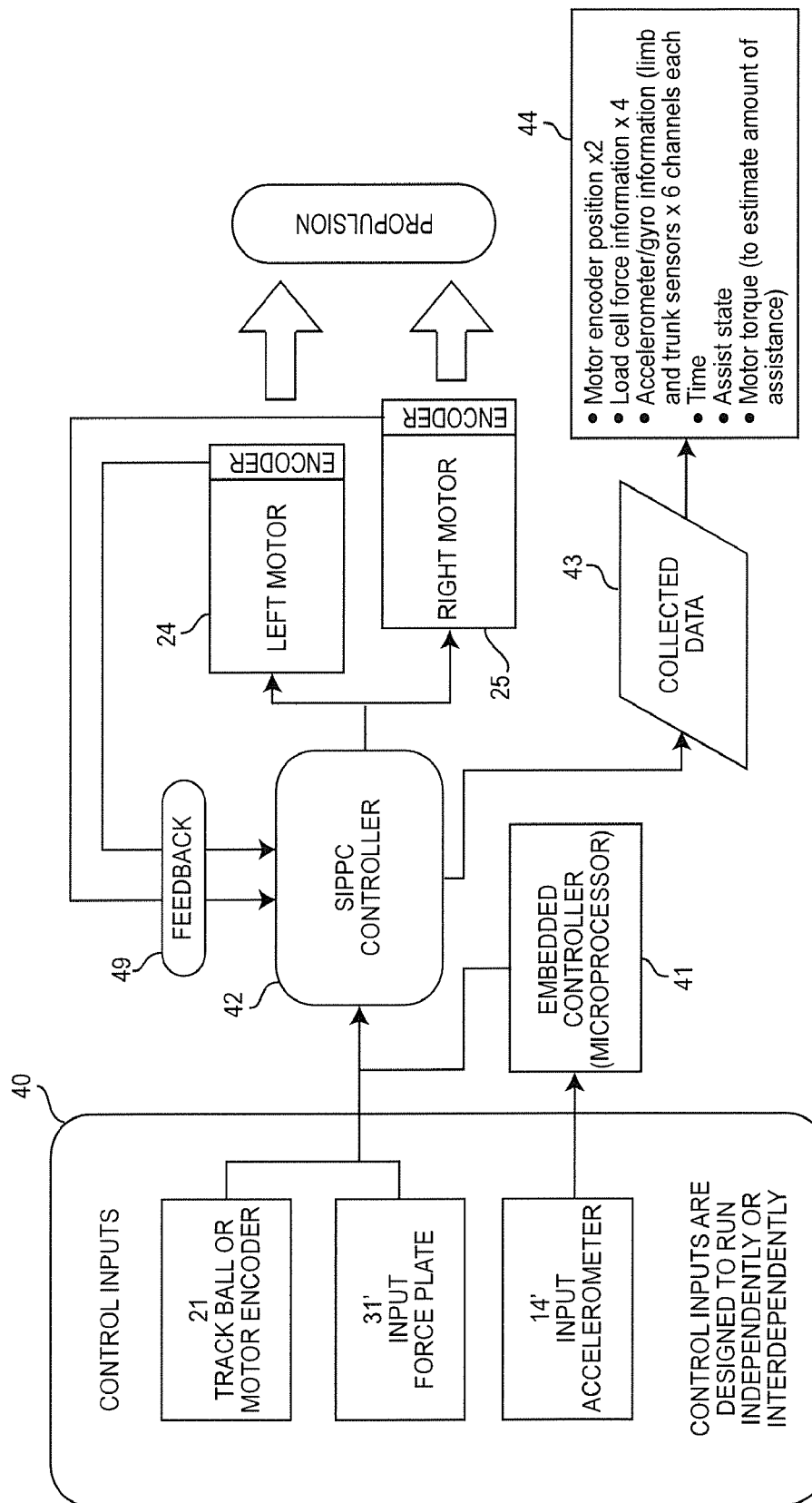


Fig. 6

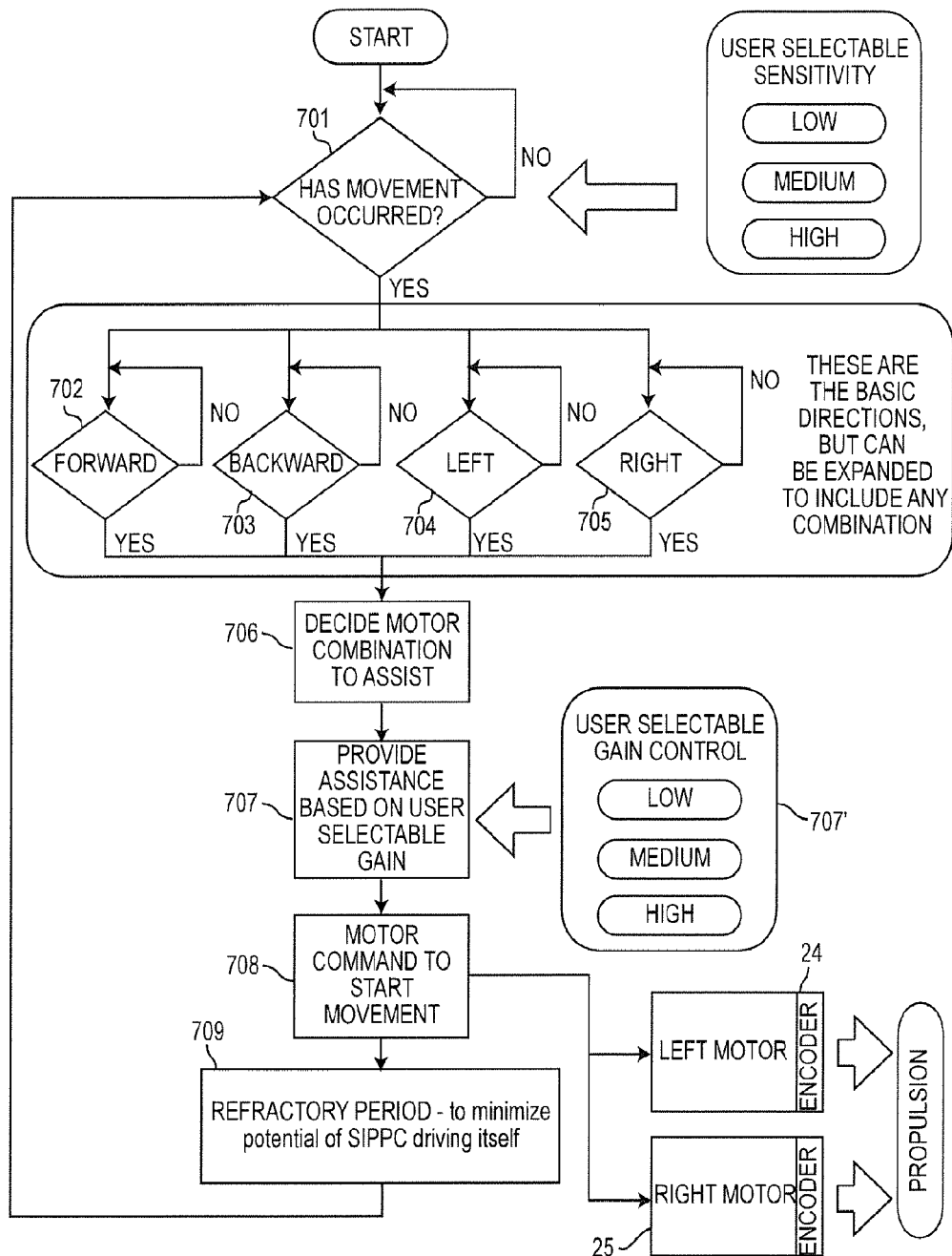
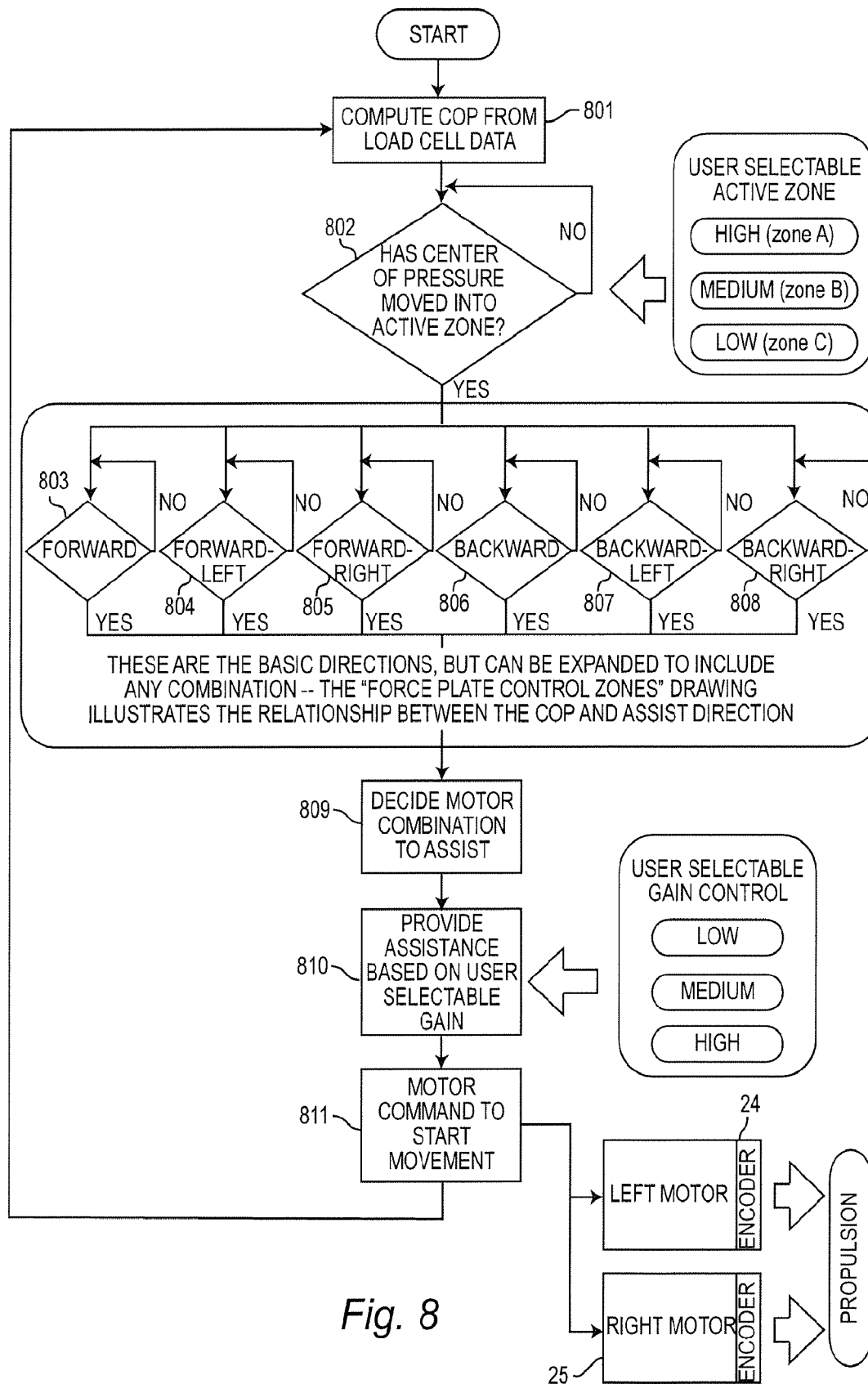


Fig. 7



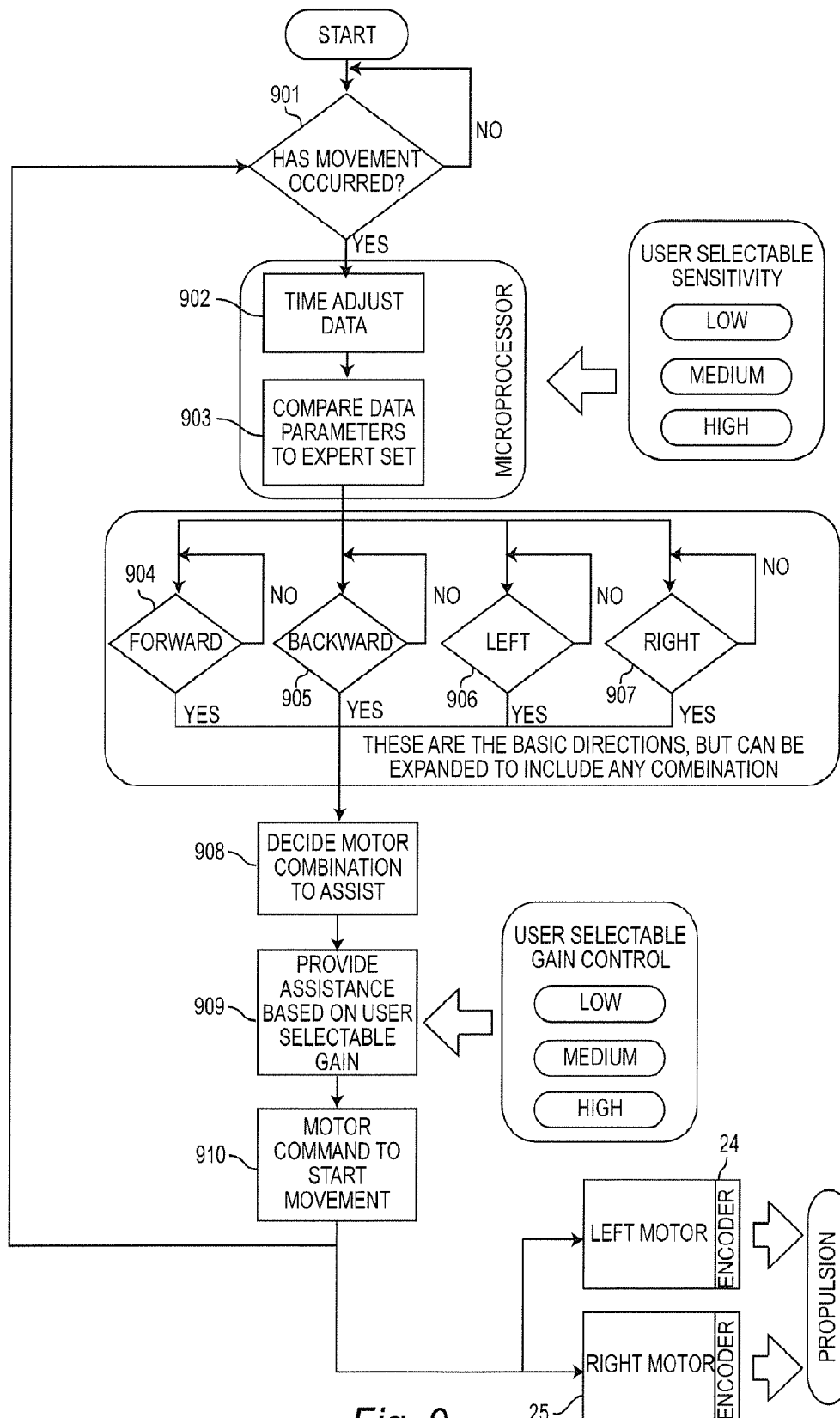


Fig. 9

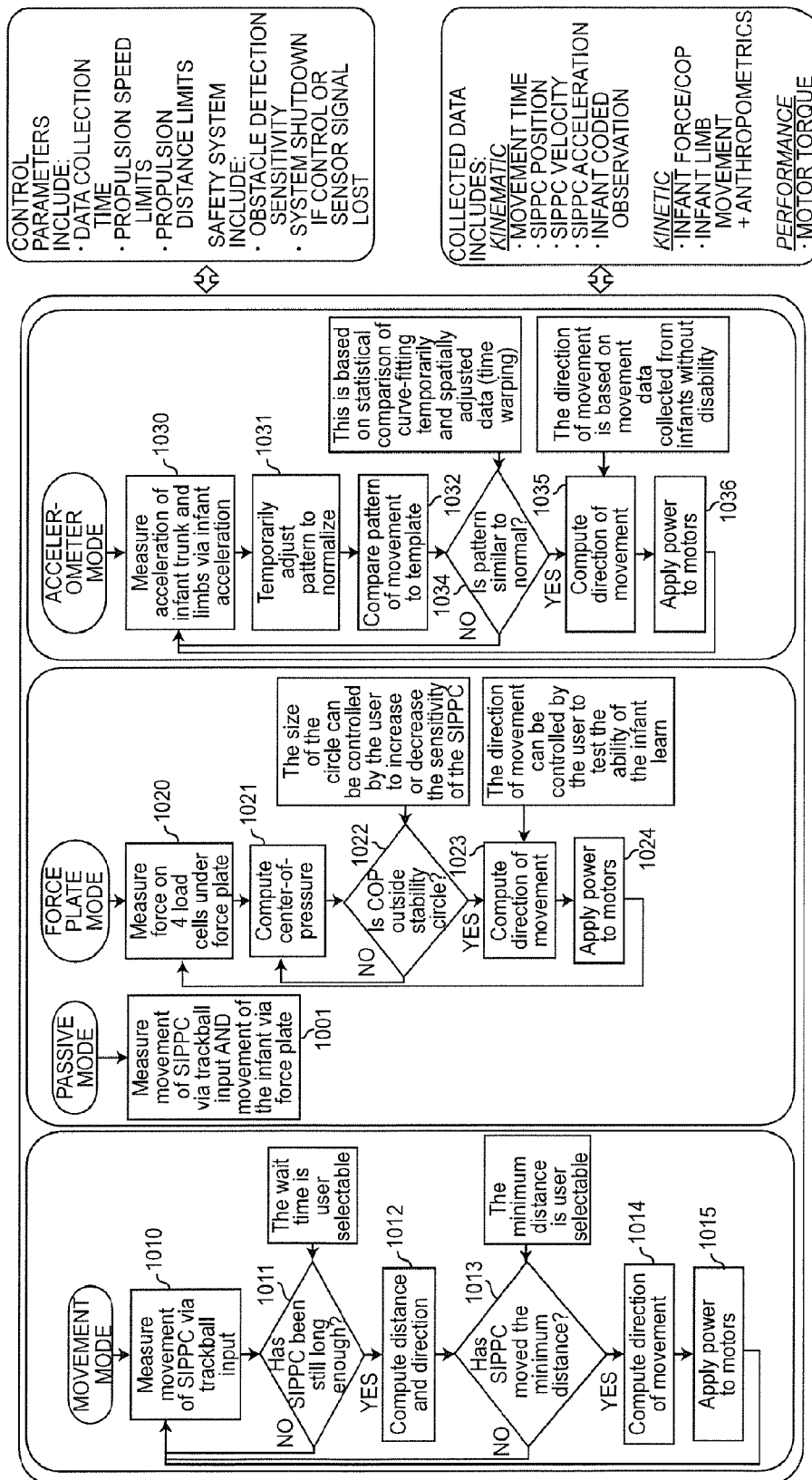


Fig. 10

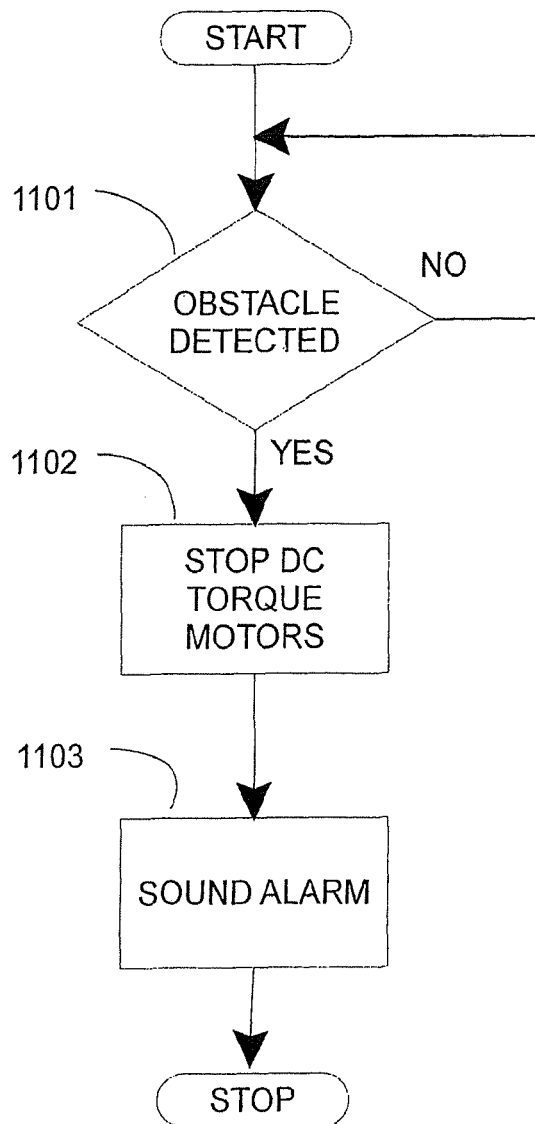


FIG. 11

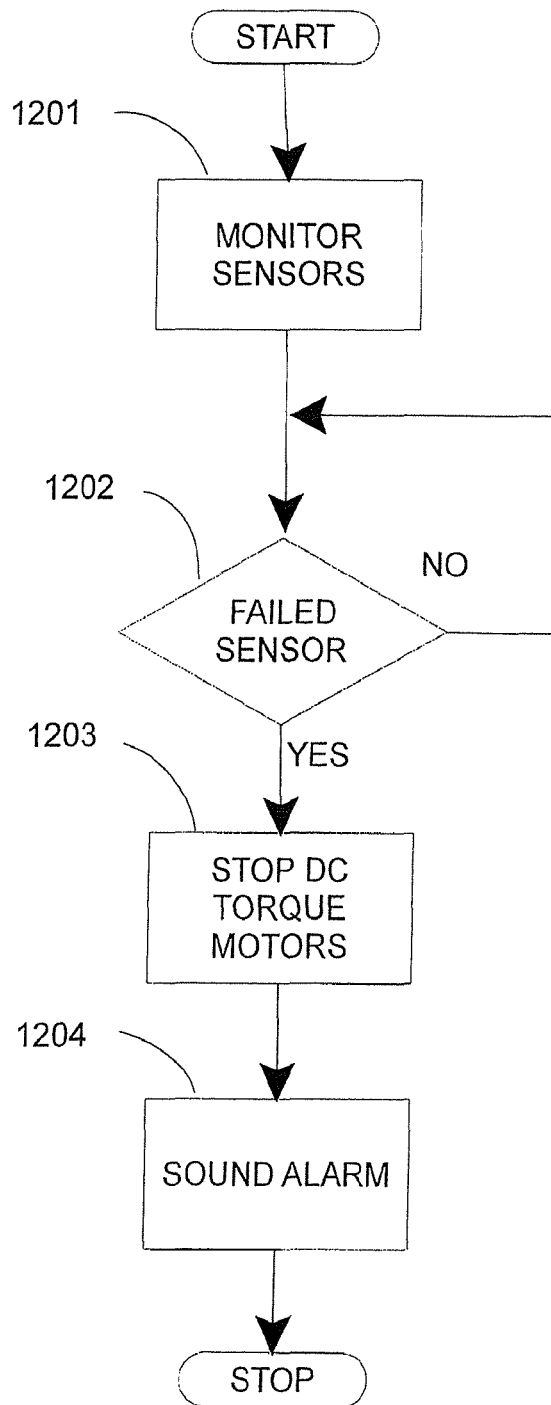


FIG. 12

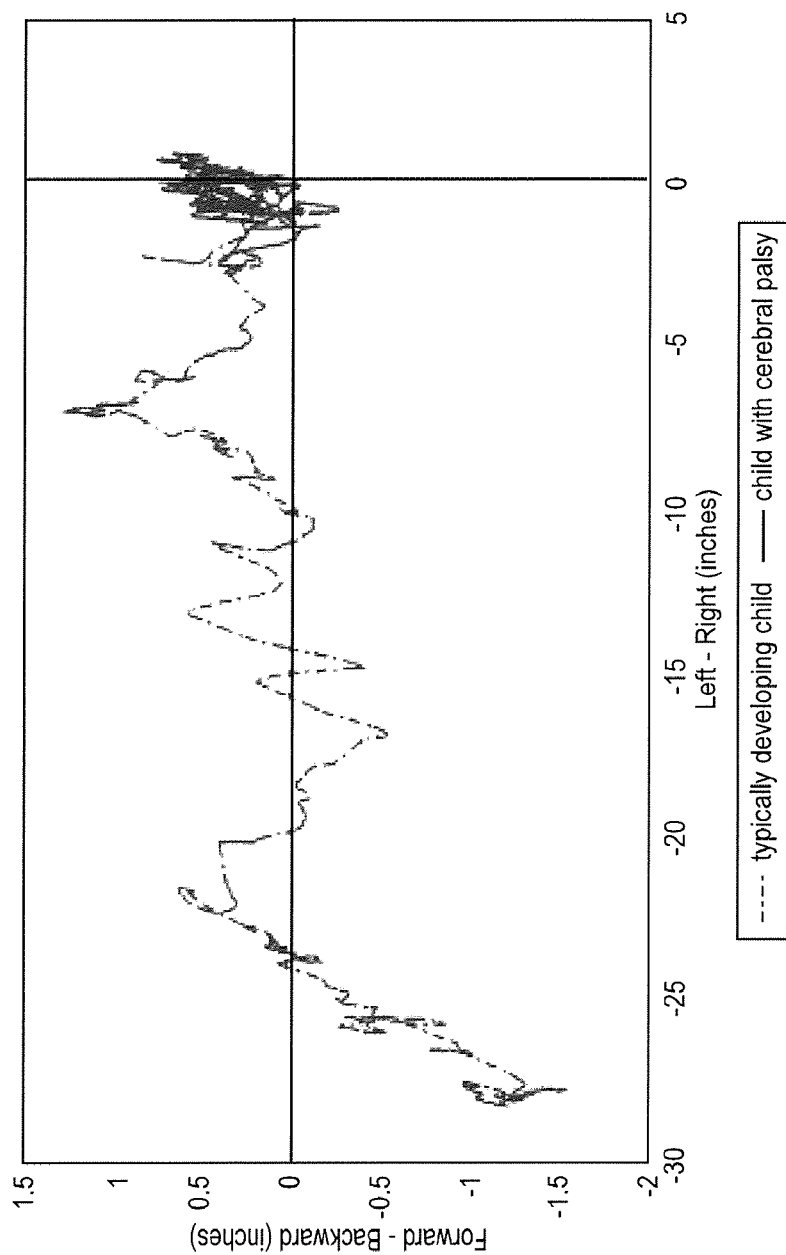


Fig. 13

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SELF INITIATED PRONE PROGRESSIVE CRAWLER

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Rule 371 application of international application PCT/US2011/37276 filed May 20, 2011, which claims the benefit of U.S. Provisional Application 61/346,527 filed May 20, 2010.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to a device which facilitates crawling in infants who are unable to perform the act of locomotion and, more particularly, to a motorized wheeled platform that senses the infant's intent and provides gentle encouragement to assist movement.

2. Background Description

Infants with disabilities, such as cerebral palsy, Down's syndrome, and spina-bifida, have difficulty with early locomotion. Currently, therapists guide the child manually based on their clinical judgment of intention.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a device which facilitates crawling in infants by sensing the infant's intent and assisting movement.

According to the invention, a self initiated prone progressive crawler is designed as a mobility aid to assist an infant in prone locomotion. The infant can be placed in a prone position and secured with loop straps. The arms and legs are unconstrained and are able to reach the floor comfortably. The self initiated prone progressive crawler is a motorized wheeled platform designed to fit a 4 to 24 month old infant (weight range from 15 to 35 lbs). An embodiment of the device has three points of contact with the ground. One point is an industrial trackball, mounted upside down to provide positional and positional derivative data to a controller. It may be located roughly under the chest of the infant and can be highly sensitive to movement. The other points of contact are two DC torque motors which are controlled by the controller. In addition to the positional and positional derivative data provided to the controller, the controller may also receive data from four equally spaced load cells on a force plate and tri-axial accelerometer gyros attached to the upper and lower extremities of the child. The load cells provide force information between the infant and the device to allow weight shifts to be assessed and used as a control parameter. The accelerometer gyros generate data that provides patterns that can be correlated to crawling. These patterns can be used to develop control algorithms for the device.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, aspects and advantages will be better understood from the following detailed description of a preferred embodiment of the invention with reference to the drawings, in which:

FIGS. 1a-b are top and side pictorial diagrams illustrating an infant attached to the self initiated prone progressive crawler according to the invention;

FIGS. 2a-b are bottom and side views of the self initiated prone progressive crawler showing the track ball and the DC torque motor driven wheels which constitute the three-point contact with the ground;

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FIGS. 3a-b are top and side views of the self initiated prone progressive crawler showing the circular platform attached to the body of the self initiated prone progressive crawler via four equally spaced load cells;

FIG. 4 is a schematic diagram of the force plate mounted to the top of the platform;

FIG. 5 is a diagram illustrating the force plate control zones;

FIG. 6 is a schematic diagram showing the interrelationship of the functional components of the self initiated prone progressive crawler;

FIG. 7 is a flow diagram illustrating the logic of the software that implements the trackball algorithm;

FIG. 8 is a flow diagram illustrating the logic of the software that implements the force plate algorithm;

FIG. 9 is a flow diagram illustrating the logic of the software that implements the accelerometer algorithm;

FIG. 10 is a flow diagram illustrating the logic of the several modes of operation of the self initiated prone progressive crawler according to the invention;

FIG. 11 is a flow diagram illustrating the logic of the software that implements obstacle detection and avoidance of the invention;

FIG. 12 is a flow diagram illustrating the logic of the software that implements the system shutdown operation of the invention; and

FIG. 13 is a chart of path data (total distance traveled) illustrating the small area traversed by a child with cerebral palsy compared to a typically developing child.

DETAILED DESCRIPTION

Referring now to the drawings, and more particularly to FIGS. 1a-b, 2a-b, and 3a-b, there is shown the self initiated prone progressive crawler 10 on which an infant 11 is secured in a prone position on the platform 12 of the device with the aid of hook and loop straps 13. As best shown in FIG. 2, the device has three points of contact with the ground. One point is an industrial trackball 21, mounted upside down to provide positional and positional derivative data to the controller. It is located roughly under the chest of the infant and is highly sensitive to movement. The other points of contact are two wheels 22 and 23 driven by respective DC torque motors 24 and 25. In one embodiment, the motors 24 and 25 are capable of producing 36 in-lbs of torque and can propel an infant weighing up to 35 lbs at a rate of three feet/min, yet are low friction when non-powered. The motors are linked to a multi-axis controller running custom software, as shown in FIG. 6 and described in more detail with reference to FIGS. 7 to 9. The electronics for the controller and data collection are located in a housing 26 between the DC torque motors. In addition, there are in the embodiment shown five infrared (IR) sensors 27 located at points around the periphery of the platform 12 of the device. These are for detecting obstacles. As best shown in FIG. 3a, the top of the self initiated prone progressive crawler is a force plate 31, shown in more detail in FIG. 4, in the form of a circular clear plastic platform attached to the platform 12 of the device via four equally spaced load cells 32, 33, 34, and 35 located under the infant's body. As shown in FIG. 4, the load cells support the force plate and, by their geometry, define zones that provide force information between the infant and the device to allow weight shifts to be assessed and used as a control parameter. FIG. 5 illustrates an example of how these zones are interpreted in terms of accessing the infant's intention. In addition, as shown in FIG. 1, tri-axial accelerometer gyros 14 may be attached to the upper and lower extremities of the child. The

configuration of the device is designed to sense movement, determine the infant's intent, and engage the motors to facilitate that intent.

FIG. 6 shows the relationship of the functional components of the self initiated prone progressive crawler. The control inputs **40** may include any or all of the trackball **21** (see trackball or motor encoder **21**), the load cells **32**, **33**, **34**, and **35** attached to the force plate **31** (see input for forceplate **31'**), the tri-axial accelerometer gyros **14** (see input for gyros **14'**), and the IR detectors **27**. In some applications, other types of input might be employed (e.g., sonar or radar input may be employed). The outputs of the accelerometer gyros **14** are input to an embedded controller **41**, which provides an input, together with the outputs of the trackball **21** and the load cells **32**, **33**, **34**, and **35** to the self initiated prone progressive crawler (SIPPC) controller **42**. Custom software, described in more detail with reference to FIGS. 7 to 9, provides control of the self initiated prone progressive crawler using a multi-axis controller **42** designed for robotics applications. Data collection may be accomplished by using a Microsoft Excel custom application **43** that allows data to be transferred and stored from a TCP/IP (Transmission Connection Protocol/Internet Protocol) connection. All self initiated prone progressive crawler data may be collected to a worksheet. Real-time graphs are displayed at **44** when the device is active. The SIPPC controller **42** controls a left DC torque motor **24** and a right DC torque motor **25**. These are provided with analog-to-digital (A/D) encoders **47** and **48**, respectively, which provide outputs to feedback loop **49**.

The trackball algorithm implemented on the SIPPC controller **42** is illustrated in FIG. 7. The trackball **21** can be adjusted for sensitivity to movement. In the embodiment shown, the sensitivity levels are low, medium and high; however, fewer or greater number of sensitivity levels may be provided or, in the alternative, the sensitivity level may be pre-programmed. The first step in the software process is decision block **701** in which movement is detected. If movement is detected, the process goes to each of the decision blocks **702**, **703**, **704**, and **705** to determine if the detected movement is forward, backward, left, right, or a combination of these. Depending on the results of the decisions made in decision blocks **702**, **703**, **704**, and **705**, a determination is made in function block **706** as to the motor combination required to assist the infant in directional movement. The output of function block **706** is provided to function block **707** where the amount of assistance to be provided is determined. In the embodiment shown, the gain control **707'** for function block **707** can be adjusted for low, medium and high gain; however, fewer or greater number of gain levels can be provided or, rather than discrete levels of gain control, the gain control can be continuously variable. In another alternative, the gain control **707'** can be pre-programmed. The output of function block **707** is used in function block **708** to generate control signals to the left and right DC torque motors **24** and **25**. Function block **708** also provides input to function block **709** which provides feedback to decision block **701**.

The forceplate algorithm implemented on the SIPPC controller **42** is illustrated in FIG. 8. The active zone (see FIG. 5) of the forceplate **31** can be adjusted in the embodiment shown. The active zones are low, medium and high; however, fewer or greater number of sensitivity zones may be provided or, in the alternative, the sensitivity level may be pre-programmed. The first step in the software process is function block **801** where the center-of-pressure (COP) is computed from the load cell data. Then in decision block **802** a decision is made as to whether the center of pressure has moved to an active zone. If so, the process goes to each of the decision

blocks **803**, **804**, **805**, **806**, **807**, and **808** to determine if the detected center of pressure is forward, forward left, forward right, backward, backward left, backward right, or a combination of these. Depending on the results of the decisions made in decision blocks **803**, **804**, **805**, **806**, **807**, and **808**, a determination is made in function block **809** as to the motor combination required to assist the infant in directional movement. The output of function block **809** is provided to function block **810** where the amount of assistance to be provided is determined. In the embodiment shown, the gain control for function block **810** can be adjusted for low, medium and high gain; however, fewer or greater number of gain levels can be provided or, rather than discrete levels of gain control, the gain control can be continuously variable. In the alternative, the gain control can be pre-programmed. The output of function block **810** is used in function block **811** to generate control signals to the left and right DC torque motors **24** and **25**. Function block **811** also provides feedback to function block **801**.

The accelerometer algorithm implemented on the SIPPC controller **42** is illustrated in FIG. 9. The first step in the software process is decision block **901** in which movement is detected. If so, the detected movement is output to the embedded controller **41** in which time adjust data is accessed in function block **902**, and this data is compared to data parameters in an expert set in function block **903**. In the embodiment shown, the sensitivity levels of the embedded controller can be adjusted as low, medium and high; however, fewer or greater number of sensitivity levels may be provided or, in the alternative, the sensitivity level may be pre-programmed. The process next goes to each of the decision blocks **904**, **905**, **906**, and **907** to determine if the detected movement is forward, backward, left, right, or a combination of these. Depending on the results of the decisions made in decision blocks **904**, **905**, **906**, and **907**, a determination is made in function block **908** as to the motor combination required to assist the infant in directional movement. The output of function block **908** is provided to function block **909** where the amount of assistance to be provided is determined. In the embodiment shown, the gain control for function block **909** can be adjusted for low, medium and high gain; however, fewer or greater number of gain levels can be provided or, rather than discrete levels of gain control, the gain control can be continuously variable. In the alternative, the gain control can be pre-programmed. The output of function block **909** is used in function block **910** to generate control signals to the left and right DC torque motors **24** and **25**. Function block **910** also provides feedback to decision block **901**.

The software illustrated in the flow diagrams of FIGS. 7 to 9 has been developed with infant safety in mind while providing the experimenter with the flexibility to modify control parameters to positively influence the interaction between the infant and the self initiated prone progressive crawler. The software supports four modes of operation: passive mode, active trackball or movement mode, active forceplate mode, and accelerometer mode. All modes produce a level of assistance (or resistance) that can be part of an adaptive algorithm that decides how much to provide. The software which implements these modes is shown in flow diagram form in FIG. 10.

In the passive mode, the DC torque motors **24** and **25** are non-active and the device collects movement data from the trackball **21** and motor encoders **47** and **48** at function block **1001**. Force data from the load cells on forceplate **31** is also collected and the center-of-pressure (COP) of the infant is computed and plotted. Accelerometer/gyro data will also be plotted when available.

In the active trackball or movement mode, the DC torque motors **24** and **25** are active and the device responds to input from the trackball **21**. The infant must initiate movement with significant amplitude to be registered on the trackball sensor. The SIPPC controller **42** commands the motors to propel the self initiated prone progressive crawler in the direction of the disturbance. The distance and rate of movement are limited and the infant must re-engage the device to continue to get the assist. The process begins in function block **810** where a movement measurement of the self initiated prone progressive crawler is made via the trackball input. A determination is made in decision block **1011** as to whether the self initiated prone progressive crawler has been still long enough. The wait time is selectable by the user. If the wait time is determined to be long enough, the distance and direction are computed in function block **1012**; otherwise, the process returns to function block **1010**. Next, a determination is made in decision block **1013** as whether the self initiated prone progressive crawler has moved the minimum distance. Again, the minimum distance is selectable by the user. If the movement is the minimum distance, the direction of movement is computed in function block **1014**; otherwise, the process returns to function block **1010**. Then in function block **1015**, power is applied to the DC torque motors **24** and **25** before the process returns to function block **1010**.

In the active forceplate mode, the DC torque motors **24** and **25** are active and the device responds to changes in the COP recorded between the infant and the device via the forceplate **31**. This mode of operation is equivalent to a "body self initiated prone progressive crawler control algorithm mouse". When the infant is centered on the device, their COP is typically near the center of the force plate **31**. During crawling attempts or extremity movement, the COP will move in proportion to the redistribution of body mass. This occurs in a predictable pattern. Changes in the COP result in motor activation to propel the self initiated prone progressive crawler in the direction of intended movement. Movement assistance is again limited to encourage the infant to stay actively involved in the locomotion process. Sensitivity is controlled by creating a virtual no-assistance zone in the center of the forceplate. The motors will not activate if the COP is within this zone; the smaller the zone, the more sensitive the device to COP movements. The process begins at function block **1020** where the force on the four load cells **32**, **33**, **34**, and **35** under the forceplate **31** is measured. Based on this measurement, the COP is computed in function block **1021**. A determination is made in decision block **1022** as to whether the COP is outside the stability circle. The size of the circle can be controlled by the user to increase or increase the sensitivity of the self initiated prone progressive crawler. If the COP is outside the sensitivity circle, the direction of movement is computed in function block **1023**; otherwise, the process returns to function block **1021**. The direction of movement can be controlled by the user to test the ability of the infant to learn. Based on the computed direction of movement, power is applied to the DC torque motors **24** and **25** in function block **824** before the process returns to function block **1020**.

In the active accelerometer mode, the DC torque motors **24** and **25** are again active and the device responds to movement data acquired from the limbs and trunk of the infant. This is accomplished by using tri-axial accelerometer gyros **14** attached to the upper and lower extremities of the child. This type of movement data provides patterns that can correlated to crawling allowing movement of the self initiated prone progressive crawler with "virtual" crawling. The infant does not need to touch the floor or physically move the self initiated

prone progressive crawler, the infant only needs to move his or her limbs in space. Because of the variation in data between and within crawling movements, the kinematics would be adjusted to recognize patterns associated with intended crawling activity. Force plate and track ball data may be used to refine this decision algorithm. The process begins in function block **1030** where acceleration of the infant trunk and limbs is measured via the tri-axial accelerometer gyros **14**. Next, a temporary adjustment to the pattern is made to normalize the measurement in function block **1031**. The pattern of movement is compared to a template in function block **1032**. A decision is then made as to the pattern is similar to normal. This determination is based on a statistical comparison of curve-fitting temporally and spatially adjusted data (i.e., time warping). If the pattern is similar to normal, the direction of movement is computed in function block **1035**; otherwise, the process returns to function block **1030**. Finally, power is applied to the DC torque motors **24** and **25** in function block **1036** before the process returns to function block **2030**.

In each of these modes of operation, the control parameters include data collection time, propulsion speed limits, and propulsion distance limits. The safety system includes obstacle detection and system shutdown if control or sensor signal is lost. Referring first to FIG. **11**, there is shown the flow diagram illustrating the logic of the software that implements obstacle detection. The inputs for obstacle detection are the IR sensors **27**, shown in FIG. **2**. The process starts in decision block **1101** where a determination is made as to whether an obstacle has been detected. The obstacle could be a wall, stairs, furniture, etc. The nature of the obstacle is not important. In one embodiment, the self initiated prone progressive crawler device may be stopped before the infant encounters the obstacle. If an obstacle is detected, the controller **42** stops the DC torque motors **24** and **25** in function block **1102**. Then in function block **1103**, an alarm may be sounded to notify the user that the infant is about to encounter an obstacle. In addition to an audible alarm, a light may be placed on the platform and made to flash in function block **1103**.

An example of the system shutdown is shown in FIG. **12**, which shows the flow diagram illustrating the logic of the software that implements this feature. The process begins in function block **1201** where the controller **42** monitors the several sensors; i.e., the trackball **21**, the force plate **31**, the accelerometer gyros **14**, and the IR sensors **27**. A determination may be made in decision block **1202** as to whether a sensor has failed. If so, the controller **42** can stop the DC torque motors **24** and **25** in function block **1203**. Then in function block **1204**, an alarm may be sounded to notify the user that a sensor has failed. As in the obstacle detection software, in addition to an audible alarm, a light may be placed on the platform **12** and made to flash in function block **1204**. In each of these two processes, the audible and/or flashing light signal may be different in terms of frequency or pattern to provide an indication to the user as to the nature of the fault. Once the fault has been corrected, e.g., the obstacle removed or sensor replaced, the system may require resetting prior to continued use.

The collected data includes kinematic data, kinetic data and performance data. the kinematic data includes movement time, self initiated prone progressive crawler position, self initiated prone progressive crawler velocity, self initiated prone progressive crawler acceleration, and infant coded observation. The kinetic data includes infant force (i.e., the COP) and infant limb movement (i.e., the tri-axial accel-

ometer gyros) plus anthropometrics. The performance data collected is the DC motor torque.

Safety has been addressed on several levels.

1. The device design provides no sharp edges or exposed electromechanical components. The top surface is padded and head support is provided. It is low to the ground, promoting extremity contact and, facilitating a quadruped position for locomotion.
2. The motors and controller are designed to limit propulsion speeds via both software and hardware limit switches. This provides two layers of protection; one that is hardwired and one that is based on software decisions.
3. Propulsion distance is also limited following an activation event. The device is not designed to provide continuous facilitation. When assistance is triggered, the motors engage for a brief period to facilitate movement in the triggered direction. This parameter is under experimenter control, but is limited to a maximum of 500 ms. The default is 300 ms on system start-up.
4. All control logic circuits employ a failsafe design such that if the signal between any components in the system were lost, the system disables itself.
5. Infrared proximity detectors are mounted on the device to eliminate contact between the self initiated prone progressive crawler and vertical surfaces, and to prevent accidental stairs descent. Again, these circuits are designed such that if the signal from these detectors is lost, the system disables itself.
6. The final intrinsic safety feature is supervision. It is required that use of the self initiated prone progressive crawler will be under supervised conditions at all times.

A novel feature of the invention is the packaging. The controller, motors, and input transducers are all housed on the self initiated prone progressive crawler in a configuration that has a profile low enough for the infant to reach the floor. The only connection between the device and the "outside world" may be a CAT5 (Category 5) computer cable and a power cable. Wireless control may also be employed.

The modes of control are also novel and allow a progression of infant motor-development plans to be implemented. It was designed with research flexibility in mind. It can easily be modified to include future control ideas and combinations of existing control ideas.

The device was designed with research in mind and has been tested on children with Cerebral Palsy (CP). Early data suggests that it does provide facilitated movement. Children with CP do not typically explore their environment like typically developing children. FIG. 13 illustrates a pattern of movement for two subjects. When the self initiated prone progressive crawler is in an active mode, the child with CP can move the device like a young infant with typical development.

The device also has utility, not just for children with disabilities, but also for the normally developing child. Facilitating early movement may have some intrinsic benefit to the development of motor coordination and promotes early exploration. The device is unique and innovative in that it does not only serve as an assist or intervention device, but can also be used to gather much needed comprehensive information about how infants with brain lesions learn new motor skills.

Electronic components continue to get smaller and lighter with each generation. The next step is to reduce the need for external power by supplying that power with on-board batteries. The data collection cable could also be replaced with a wireless interface.

While the invention has been described in terms of a single preferred embodiment, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the appended claims.

Having thus described our invention, what we claim as new and desire to secure by Letters Patent is as follows:

1. A device which facilitates crawling in infants comprising:

a platform on which an infant can be positioned prone with arms and legs in contact with a surface below the platform, on which surface said platform is moveable; one or more sensors for detecting arm and leg movements of the infant on the platform;

a controller receiving outputs from the one or more sensors for assessing an intended direction of movements of the infant based on detected arm and leg movements; and

a motive device controlled by the controller for moving the platform in the intended direction assessed by the controller to assist the infant in locomotion.

2. The device of claim 1, wherein the one or more sensors comprises:

a force plate mounted on the platform on which the infant rests; and

a sensor attached to the force plate for sensing center-of-pressure (COP) of the infant.

3. The device of claim 2, wherein the sensor for sensing COP comprises four load cells supporting the force plate on the platform.

4. The device of claim 1, wherein the one or more sensors comprises:

a trackball mounted upside down under the platform at a position located roughly under the chest of the infant; and

a sensor attached to the trackball to provide positional and positional derivative data.

5. The device of claim 4, wherein the motive device comprises:

first and second wheels which together with the trackball comprise three points of contact with the ground; and

first and second DC torque motors connected to drive respective ones of the first and second wheels, said first and second DC torque motors being responsive to the controller to move the platform in a direction that reflects an infant's intent.

6. The device of claim 1, wherein the one or more sensors comprises tri-axial accelerometer gyros which are adapted to be attached to the extremities of an infant.

7. The device of claim 1, wherein the one or more sensors comprises:

a force plate mounted on the platform on which the infant rests;

a first sensor attached to the force plate for sensing center-of-pressure (COP) of the infant;

a trackball mounted upside down under the platform at a position located roughly under the chest of the infant; and

a second sensor attached to the trackball to provide positional and positional derivative data.

8. The device of claim 7, wherein the first sensor for sensing COP comprises four load cells supporting the force plate on the platform.

9. The device of claim 7, wherein the motive device comprises:

first and second wheels which together with the trackball comprise three points of contact with the ground; and first and second DC torque motors connected to drive respective ones of the first and second wheels, said first

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and second DC torque motors being responsive to the controller to move the platform in a direction that reflects an infant's intent.

10. The device of claim 1, wherein the one or more sensors comprises:

- a force plate mounted on the platform on which the infant rests;
- a first sensor attached to the force plate for sensing center-of-pressure (COP) of the infant;
- a trackball mounted upside down under the platform at a position located roughly under the chest of the infant;
- a second sensor attached to the trackball to provide positional and positional derivative data; and
- tri-axial accelerometer gyros which are adapted to be attached to the extremities of an infant.

11. The device of claim 1, wherein the controller is programmed to control the motive device to drive the platform a specified distance at a specified speed.

12. The device of claim 11, wherein the controller is programmed to vary one of the specified distance and specified speed.

13. The device of claim 11, wherein the controller is programmed to drive the platform a specified distance at a specified speed only when a center-of-pressure (COP) of the infant on the platform is outside a specified zone.

14. The device of claim 1, further comprising a sensor for sensing when the platform is near an obstruction and providing an input to the controller, said controller being programmed to stop motion of the platform in a vicinity of the obstruction.

15. The device of claim 1, wherein the controller is programmed to monitor the one or more sensors and, upon detection of a fault in the sensor means, to stop motion of the platform.

16. A method for facilitating crawling in infants which is implemented with a comprising a platform on which an infant can be positioned prone with arms and legs in contact with a surface below the platform, on which surface said platform is moveable, one or more sensors for detecting arm and leg movements of the infant on the platform, a controller receiving outputs from the one or more sensors, and a motive device for moving the platform, the method comprising the steps of: assessing by the controller based on the outputs from the one or more sensors intended movements made by the

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infant which correspond to detected arm and leg movements while the infant is on the platform; controlling by the controller the motive device to assist the infant in locomotion based on assessed intentions of the infant.

17. The method of claim 16, wherein the controller determines center of pressure (COP) of the infant on the platform, the COP determination being used by the controller to access intended movements of the infant.

18. The method of claim 16, wherein the one or more sensors includes a trackball mounted upside down under the platform at a position located roughly under the chest of the infant, said trackball including a sensor to provide positional and positional derivative data to the controller, the positional and positional derivative data being used by the controller to access intended movements of the infant.

19. The method of claim 16, wherein the one or more sensors include tri-axial accelerometer gyros which are adapted to be attached to the extremities of an infant, accelerometer data provided to the controller being used by the controller to access intended movements of the infant.

20. The method of claim 16, wherein the controller determines center of pressure (COP) of the infant on the platform, wherein the one or more sensors includes a trackball mounted upside down under the platform at a position located roughly under the chest of the infant, said trackball including a sensor to provide positional and positional derivative data to the controller, the COP determination and positional and positional derivative data being used by the controller to access intended movements of the infant.

21. The method of claim 16, wherein the controller determines center of pressure (COP) of the infant on the platform, wherein the one or more sensors includes a trackball mounted upside down under the platform at a position located roughly under the chest of the infant, said trackball including a sensor to provide positional and positional derivative data to the controller, and wherein the one or more sensors further includes tri-axial accelerometer gyros which are adapted to be attached to the extremities of an infant, the COP determination, positional and positional derivative data and accelerometer data from the tri-accelerometer gyros being used by the controller to access intended movements of the infant.

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